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DENIEL

ON

PANAMA CANAL

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The Canadian Society of Civil Engineers.

THE PANAMA CANAL.

BY

E. DENIEL,

M. CAN. SOC. C. E.

BY PERMISSION OF THE COUNCIL.

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THE PANAMA CANAL.

By E. DENIEL, M. CAN. SOC. C. E.

Twenty years hardly had elapsed since the discovery of the new continent, when Saavedra, a Spaniard, proposed to cut a canal through the Isthmus of Darien (1520), and only eight years later, the Portuguese, Antonio Galvao, indicated four different routes through the Isthmuses of Mexico, Nicaragua, Panama and Darien.

The idea of uniting the Atlantic and Pacific Oceans has never been abandoned since, and, successively or simultaneously, Spaniards, Portuguese, Englishmen, Frenchmen, Americans, Belgians, etc., have explored the American Isthmus, with the hope of finding an adequate solution to that mighty problem. Navigators, soldiers, engineers, financiers, scholars, even princes and kings, have been attracted by the desire to attach their names to that great work, and have devoted to it time, labor and money.

Wealth and science, walking hand in hand, cannot fail to attain their goal, and after two hundred and sixty years of hard toil the execution of that gigantic enterprise has at last been undertaken.

It is not the object of this communication to give a history or even a sketch of all the works and discoveries made by these daring pioneers; but, without in any way lessening the share of fame and glory achieved by the present promoters and directors, it must not be forgotten that they have been reaping the benefit of the explorations made by their predecessors, and that if to-day the period of execution has been opened, it is due as much to the pressing need of means of rapid communication as to the energy and ability displayed by Messrs. Wise, de Lesseps, and others.

The meeting of the "Congrès International," in 1879, the formation of the "Société Internationale du Canal Interocéanique de Panama," in 1880, and the opening of the works in 1881, are events still fresh in every memory; we will therefore enter at once into a description of the proposed Panama Canal, and of the works executed up to January 1st, 1888.

The length of the canal is, from deep water to deep water, $75 \frac{9.5.0}{1.0.0}$ kilometers, or $47 \frac{1.3.0}{1.0.0}$ miles. Starting from Colon, on the Atlantic Coast, the canal follows the shore of Limon Bay for some three miles, and about three miles further strikes the valley of the Río Chagres, crossing for the first time the bed of that river; then it follows the general direction of that valley up to Gamboa, a distance of $22 \frac{2}{3}$ miles. At

that point, the Rio Chagres changes its course nearly at right angles, but the canal continues from here in a nearly straight line towards the shores of the Pacific Ocean, following first the valley of the Rio Obispo, one of the tributaries of the Rio Chagres, for about five miles. There it has reached the backbone of the Isthmus; no more valleys, no more "rios," but only a depression in the chain of mountains that have formed a barrier between the two Oceans. Through this, hardly two miles, passes the canal. On the western slope, the valley of the Rio Grande brings it to the sea-shore eight miles distant, and a cut in Panama Bay three miles and a half in length, is all that is now needed to reach deep water. The Rio Chagres, Rio Obispo, and Rio Grande are very tortuous, winding rivers, running with a swift current, carrying along trees and debris of all sorts, constantly forming shoals of these materials, and shifting them here and there. Properly speaking they are torrents, and their discharge varies within very considerable limits, but within very short periods of time. The Rio Chagres, for instance, has, at Gamboa, a discharge of 2,500 gallons per second during the dry season, but this increases to 43,000 gallons per second during the wet season, and is known even to have been 130,000 during freshets. These freshets are very rapid; it is a common occurrence for this river to rise thirty feet in a few hours, and there are on record, though fortunately not frequent, instances of sudden rises of fifty feet.

The plan at first proposed by Mr. Wise was to create in rear of Gamboa an immense reservoir, of a sufficient capacity to hold the water coming from the upper part of the river during these freshets, with outlets allowing a discharge of 43,000 gallons per second. The creation of that basin would have necessitated the erection of several dams, the main one being nearly one mile in length, one hundred and fifty feet in height, seven hundred and ninety feet in width at top, and three thousand one hundred and fifty feet at the base. As the bed of alluvial deposit is at that point ninety feet thick, this dam was to have been built of clay and rock, without any more masonry than would have been necessary for the sluice ways. The maximum height of the water in rear of this dam would have been 125 feet. Twenty-five millions of cubic yards of materials had been calculated as being required for this work.

That solution, however, has since been discarded by the engineers as too bold, while at the same time it did not afford a sufficiently satisfactory settlement to the difficulty. It was finally decided not to admit any water course into the canal, but to dig beds for the rivers on both sides. However a very large dam will have to be built at Gamboa, but without

any sluice ways, the course of the Rio Chagres being deflected through a new channel, on the left side of the canal. (*)

This dam will be about 80 feet in height, 1,600 feet in length, and 80 feet in width on the top, its two extremities butting against the cerros Santa Cruz and Obispo. It will be built of the materials excavated from the heavy cuttings near by, the core being made of clay and the outer surfaces covered with broken rock. The slopes adopted for the sides will be 2 to 1 for the upper one, and 5 to 1 for the lower one.

From Gamboa to the sea, the 10 deflections of the Rio Chagres aggregate $20\frac{1}{4}$ miles in length, the total fall of the river being some 45 or 50 feet.

The Rio Obispo flows in the Chagres near Gamboa, but on the right side of the canal, and its course generally lies on that side up to the point where it runs also at right angles to its former direction, on the left side of the canal. This river will be deflected on the right side of the canal, down to the sea, or rather down to the point where the actual bed of the Rio Chagres leaves the line of the canal to run towards Limon Bay.

This will necessitate the building of a flume bridge at kilometer 52, thrown across the canal at the height of 180 feet above sea level. This flume bridge, designated on the plan as "2nd pont-bâche," will carry the waters of the Rio Obispo and of Lake Lapita by means of two troughs, each 6 ft. 8 in. x 6 ft. 8 in. A similar bridge will be built at kilometer $48\frac{5}{100}$ to carry over the canal the waters of the Lake Margarita and of the Rio Sardanilla; the height of this bridge will be 135 feet above sea level. The length of these flume bridges will be about 500 feet. All the tributaries of the Rio Chagres, coming from the right side of the canal, the Rios Caravali, Culo Seco, Baila Monos, Caimito, Trinidad etc., will be collected in these deflections, their aggregate length being $21\frac{1}{4}$ miles.

On the Pacific Coast, the rivers will be dealt with in a similar way, the Rio Grande being deflected on the right side of the canal, and the Rios Pedro-Miguel, Caimitillo, Cardenas, etc., will be deflected on the left side. A few only of these last deflections have been located, aggregating $4\frac{3}{4}$ miles in length.

(*) The starting point of the centre line of the Panama Canal is at Colon, and all the works, deflections, etc., are also numbered from the same point, and referred to as being on the right or left side of the canal, as they would be on the right or left hand side of a man walking along the centre line towards Panama.

There are also other incidental works, as deflections of the Panama Railroad, at such places where the canal or the deflections of rivers are interfering with the railway track. These will be six in number, and will aggregate about $7\frac{1}{2}$ miles in length. A swing-bridge will have to be built across the canal near San Pablo, between kilometers 35 and 36, and another will be thrown across the canal near Pedro-Miguel between kilometers 59 and 60.

The dimensions adopted for the tide level canal were :

Width at bottom.....	72 feet.
Depth of water below mean sea level.....	29 ft. 6 ins.
Slopes from bottom to 6 ft. 7 ins. above water, uniformly	1 to 1
Width of berms on each side.....	6 ft. 7 ins.
Slopes above the berms, according to the nature of the ground,	
generally from 1 in 1 to 1 in 4.	

Near Panama, a pair of tidal gates would have in any case been necessary on account of the difference in the height of the tide in the two oceans. At Colon the difference of level between high and low tide is only 2 feet, while it is 20 feet at Panama. Consequently, the Panama end of the canal, beyond the tidal gates or lock, will be deepened to 36 feet below mean sea level.

Following in its course the bottom of the valleys, and running between the cerros, the canal has, as before stated, a length of $47\frac{1}{10}$ miles, while the distance between its two extremities, measured in a straight line, is but $40\frac{1}{2}$ miles.

Of these 47 miles, $25\frac{1}{10}$ miles are tangents, while the balance, or, $21\frac{6}{10}$ miles, is composed as follows :

2	curves of 4,000 metres radius, aggregating	1.28 miles.
3	" " 3,500 " "	4.44 "
10	" " 3,000 " "	12.39 "
4	" " 2,500 " "	3.55 "

The harbour of Colon, near the bottom of Limon Bay, is far from being safe and secure, and it is the intention of the Canal Company to enlarge that entrance of the canal to a width of 1650 feet for a distance of $2\frac{1}{2}$ miles. This harbour, protected at its entrance by a terre-plein formed of the materials coming from the excavation of the canal, will afford to the ships a much needed protection, and at the same time will be very valuable for the local commerce. The buildings of the company in Colon are erected on that terre-plein, on which stands a colossal statue of Christopher Columbus, the only work of art in the country.

A meeting basin, $2\frac{1}{2}$ miles long, will also be provided at some nineteen miles from Colon, and another one eighteen miles further on, on the western slope.

A detailed geological description of the different formations met on the line of the canal would go far beyond the limits of this succinct sketch, in which a mere mention of the principal features of the Panama Canal Works is all that can be attempted. However briefly described, the course of the canal runs for a distance of 27 miles through mud, sand, gravel, peat, unctuous and arenaceous clay, meeting occasionally with beds of soft calcareous tufa, argillous schist, limestone conglomerate, sandstone and argillite, the aggregate length of these rocky formations being only $3\frac{1}{2}$ miles. Then for 13 miles, the cut runs through a mass of hard, igneous, vitreous and metamorphic rocks, in which predominate compact limestone, volcanic agglomerates, hard sandstone, basalts, argillite, carbonaceous shale, arenaceous tufa, etc., covered however with a thick layer of clay and earth. On the western shores of the Isthmus, and in Panama Bay, the canal runs through beds of clay, sand, gravel, mud and shells, for a distance of some seven miles.

At the end of the year 1887, just seven years after the beginning of the works, the Panama Canal Company found itself in a very difficult position. It had already incurred liabilities far exceeding the cost of the canal as estimated by the congress of Paris (\$209,000,000); its financial department required some 15 or 16 millions of dollars annually; the treasury was nearly empty; seven-twelfths of the time allowed by the charter to complete the works had gone by; and yet, there was hardly one quarter of the excavation done, and that even the easiest portion.

It is true that immense preparations had been made. The Isthmus, and let this be borne in mind, enjoys the well deserved reputation of having the most insalubrious climate; there were no population, no agriculture, no manufactures, no trade, nothing, absolutely nothing there to depend upon or to help in the construction of the canal, except however the Panama Railroad. Everything had and has to be imported: laborers, contractors' plant, dwelling houses, all sorts of materials and supplies, even meat, butter, milk and water! To do this alone denotes on the part of the promoters indomitable energy and unshaken faith in the ultimate success of their enterprise. Blunders may have been committed, money may have been spent with a lavish hand, but such faults are inherent in all great works and almost beyond man's control.

The plant alone comprises: Fifty steam dredges of the most powerful built; thirty tugs; two hundred scows; one hundred and twenty steam excavators; two hundred locomotive engines; six thousand large dumping cars; two hundred miles of standard-gauge railway;

one hundred and ten miles of narrow gauge portable railway, with seven thousand small dumping cars; one hundred and thirty portable engines; five hundred pumps; three large work-shops splendidly equipped; twenty conveyors; over 11,000 lengths of large pipes for the transportation of excavated materials; dwelling houses, offices, shanties, of all descriptions and without number; and finally, two large hospitals, one of them, the Panama Hospital, being certainly one of the best equipped in the world, as it is also probably one of the most costly.

The climate of the country is not only fatal to man and beast, it also exerts a destructive action on all kinds of materials, and consequently a constant supply of new plant has to be kept up.

The force employed on the works may be estimated at twenty thousand men, mostly Jamaicans. They stand the rigour of that deadly climate better than any other race, and the yellow and Panama fevers do not make such havoc among them as among the laborers of white or yellow extraction.

One of the most important sources of delay, as one of the most uncontrollable, is that the dry season lasts only from four to five months, and that, perforce, the works have to be partly suspended during the wet season. Then occur sudden freshets; the ground, thoroughly soaked, slides in all directions; the railway tracks are carried away, or sink under the weight of the cars; and above all, exposure to the rain is, to a European, nearly equivalent to a death warrant.

However, let the enormous difficulties that have been successfully surmounted be almost without number, the preparations be as extensive, thorough and complete as possible, yet the fact remains that, by the end of 1887, the hope of completing the tide level canal, within a reasonable time and at a remunerative cost, had to be given up, and it was then resolved to modify the originally contemplated plan and to *provisionally* resort to another solution. The modifications adopted consist of the temporary substitution of a lock canal for the tide level canal, and the reduction of the draught of water in the canal to 27 feet, all through, except at the entrance at Panama.

Ten locks, 590 feet long, 60 feet wide, will be built, six of them having a fall or rise of 36 ft. 1 in., three a fall or rise of 26 ft. 3 in., and one of 35 ft. 3 in., on account of the tide on the Pacific coast. The total rise will be 160 ft. 9 in. The locks are not to be located on the centre line of the canal, but either to the right or to the left, so as not to interfere with the subsequent deepening and widening. They are also so arranged that corresponding locks on either side of the summit reach

have equal falls, and consequently may be successively done away with by pairs.

The location of the locks has been determined by the nature of the ground: Lock No. 1 will be built on a bed of limestone; Locks Nos. 2, 3, 4, 5, 6, on hard sandstone; Locks Nos. 7 and 8 on conglomerate; Lock No. 9 on dolerite; and Lock No. 10 on hard tufa.

It is estimated that some fifty millions of cubic yards of material will have to be removed to complete the lock canal, and the transformation of this to the tide level canal will embrace the removal of an additional mass of from 65 to 100 millions of cubic yards of material, according to the nature of the ground and the slopes adopted for the cuttings.

The alimentation of the lock canal will not offer any very serious difficulty. The waters of the Upper Obispo, and Upper Rio Grande will be utilized, and, when necessary, the water will be pumped from the Rio Chagres into the upper reach. It has been estimated that for a daily traffic of ten ships, this service will be effectually insured by the action of steam pumps of 4,000 horse-power. But this lock canal is at best a lame solution; the expenses connected with its maintenance will be very heavy, embracing, besides the pumping, constant dredging, necessitated by the growth of sub-marine vegetation and by the large proportion of alluvial matter carried by the waters of the rivers of this region; the locks would have to be frequently renewed; therefore it is understood that these last described works are only provisional.

The principal features of the charter of the Canal Company are:

A grant from the Colombian government of five hundred thousand hectares of land, with all the minerals therein, besides all the ground required for the canal, wharves, roads, stations, buildings of all description, etc., provided it is not private property.

On the other hand, the Colombian government is to enjoy the free use of the canal and a participation of at least five per cent. in the gross earnings of the Company, this, however, being never less than two hundred and fifty thousand dollars per year.

The company also agrees to bear all the expenses connected with the maintenance of the military forces required to insure the security of the interoceanic transit.

At the end of ninety-nine years, computed from the opening of navigation, the canal and all its appurtenances will become the property of the Colombian government.

TABLE showing the lengths of the reaches and their respective levels:

N.B. The datum or zero level is the mean level of the sea.

	Lengths in miles.	Levels of bottoms of reaches in feet.	Remarks.
Colon harbor.	0.84	— 27.07	From deep water to shore
1st Reach.	14.13	— 27.07	Including Lock No. 1
2nd "	8.94	— 0.82	" " No. 2
3rd "	4.16	25.43	" " No. 3
4th "	1.48	61.52	" " No. 4
5th "	2.61	97.61	" " No. 5
6th "	3.92	133.69	Summit reach.
7th "	0.33	97.61	Including Lock No. 6
8th "	0.31	61.52	" " No. 7
9th "	0.81	25.43	" " No. 8
10th "	1.37	— 0.82	" " No. 9
11th "	4.35	— 36.09	" " No. 10
Panama Bay.	3.85	— 36.09	From shore to deep water.

DEFLECTIONS.

Nos.	Left Bank.		Right Bank.	
	Lengths in miles.	Rivers deflected.	Lengths in miles.	Rivers deflected.
1	6.13	Rio Chagres.	1.43	Rio Obispo, &c.
2	5.21	"	.37	"
3	1.14	"	3.84	"
4	.45	"	2.05	"
5	.85	"	1.63	"
6	1.22	"	2.19	"
7	2.79	"	.57	"
8	.38	"	1.24	"
9	1.12	"	2.51	"
10	.98	"	.23	"
11	1.24	Lk. Margarita	.05	"
12	0.64	" Lapita	.18	"
12bis	.57	Rio Obispo.	} 1.68	" Rio Grande.
13	.84	Rio Pedro Miguel.		
14				
15			1.18	
16			2.73	
17				
Totals..	23.56		22.75	

DISTANCE BETWEEN SOME HARBOURS, IN NAUTICAL MILES.

	Via Cape Horn.	Via Panama Canal.	Difference.
London to San Francisco,	13,795	8,135	5,660
" — Honolulu,	13,915	9,556	4,359
Liverpool — San Francisco,	13,678	7,897	5,781
Le Havre — "	13,627	7,949	5,678
Bordeaux — Valparaiso,	8,675	7,239	1,436
New York — "	8,550	4,574	3,976
" — Panama,	11,057	1,966	9,091
" — Callao,	9,791	2,333	6,488
" — Guayaquil,	10,441	2,808	7,633
" — San Francisco,	13,334	2,468	9,056

From the Drawings accompanying this paper, Plates I & II have been prepared.

DISCUSSION.

In answer to various questions propounded by Messrs. Hannaford, J. Kennedy, Peterson, Parent and Prof. Bovey, Mr. Deniel replied as follows :—

By the first January, 1888, the amount of excavation completed ranged between 30 and 40 millions of cubic yards, and there were still about 150 million cubic yards to be removed ; roughly speaking, about one-fourth of the work had been done.

Probably no one really knew the total cost of the work remaining to be finished, as it was very difficult to make an estimate.

He thought that the difficulty of completion did not lie in the work itself, but in the matter of raising the money. The great mistake made by the promoters had been in beginning the work with a small capital, about \$60,000,000, whereas their liabilities had already reached some \$300,000,000.

He considered that \$100,000,000 would be sufficient to finish the work, which would undoubtedly stand, as there would be no danger from freshets, and the canal would only be destroyed by an earthquake.

The work was superintended by the Panama Canal Co., which had given contracts to the following firms :

Société de Travaux Publics et Constructions, 15 rue Louis-le-Grand, Paris.

MM. Vignaud, Barbaud, Blanleuil & Cie., 19 rue Louis le-Grand, Paris.

MM. Baratoux, Letellier & Cie., 4 rue de Rome, Paris.

MM. Artigue, Sonderegger & Cie., 1 rue de la Bourse, Paris.

M. Jacob, 11 Place du Commerce, Nantes.

The American Contracting & Dredging Company, New York.

The canal is divided into five divisions ; each one under the charge of a divisional engineer and staff, appointed by the Company.

The first division runs from Colon to kilometer $26\frac{35.0}{1000}$. The works, principally dredging, are carried out by the American Contracting & Dredging Co., for the canal, and by Mr. Jacob, for the deflections of the Rio Chagres on the left bank of the canal.

The second division runs from kilometer $26\frac{35.0}{1000}$ to kilometer 44. The contractors are MM. Vignaud, Barbaud, Blanleuil & Cie. Their plant consists of excavators, conveyors, dredges, large and small dumping

cars, etc. The steam excavators and conveyors do not do as much work as was expected of them. They do not work much more than one-third of the time, while the negroes work at least two thirds.

The third division runs from kilometer 44 to kilometer 53, $\frac{600}{1000}$. There lies the heaviest part of the work. The contractors are the Société de Travaux Publics et Constructions. They use very large and heavy plant, steam excavators, broad gauge railways, etc.

The fourth division runs from kilometer 53, $\frac{600}{1000}$ to kilometer 57. The contractors are MM. Artigue, Sonderegger & Cie. This division, as the preceding one, is mainly through rock cutting, and the plant employed is of the same description in both cases. The work here is carried on day and night with the aid of the electric light.

The fifth division runs from kilometer 57 to kilometer 74, $\frac{500}{1000}$ in Panama Bay. It is under contract with MM. Baratoux, Letellier & Cie., and it is mainly dredging. In the Panama Bay the material dredged was very soft, and consequently the work has been easy, but the sand for a long time kept running into the cut in such quantity, that once, during a whole week, one of the elevator dredges employed there was kept at work on the same spot, its buckets coming up full all the time. Consequently the width of the cut in the Bay of Panama is considerably larger than elsewhere. However, this portion of the work, that is from deep water to La Boca, is now completed to the full depth and width.

The heavy plant, comprising dredges, excavators, cars, rails, engines, dwelling houses, etc., belongs to the Panama Canal Company, and is rented by the contractors, who furnish only the small tools, such as picks, shovels, crow-bars, drills, etc.

The deepest cut is at the Culebra. On the centre line, it measures there 107 metres above canal bottom, but the left side of the cut starts from a point 70 metres higher, near the summit of the Cerro Culebra, and at a distance of ~~16,984~~ 16,984 metres from the centre line. By the adoption of the new plan, the depth will be reduced to about 180 feet on the centre line. The centre line of the new canal will be the same as at present, but the locks will be located either on the right or on the left of it, in order to interfere as little as possible with the contemplated subsequent deepening and widening.

The Cerro Culebra is a hill of some height. It does not slide bodily towards the canal as it has been wrongly reported, but sinks, and produces heavings in the canal, and occasional slidings. This, however, could not go on for ever, as the core of the mountain is made of rock;

it would have to stop some time, but till then there was nothing to do but to keep removing the material. These heavings were at one time so sudden that in the morning, the excavators, cars, rails, etc., were frequently found on a considerably higher level than that on which they had been left on the previous evening, and, of course, more or less damaged.

He thought, however, that the trouble would soon stop; there was not as much movement as there had been. In consequence of these disturbances, the cross sections had had to be extended 3 or 4 hundred feet beyond the summit of the slope, in order to have at least an approximate idea of the quantity of material removed by the contractors. There are bench-marks built of masonry on both sides of the canal, and these are checked by similar bench-marks built along the line of the Panama Railroad.

The idea of the high dam has been given up, but there will still be one of some 80 feet in height (see page 4).

The work in the deflections was not different from the work in the canal, nor did it entail any more difficulty.

The Panama Canal Co. does not do any of the work, but gives it out to the large contractors who generally sublet it to smaller companies. The work is measured up by the engineers of the Panama Canal Co., and by the engineers of the contractors, always acting together and checking each other. One source of delay in the progress of the works has been in the periodical freshets of the rivers, especially of the Chagres. The custom was to give a sub-contractor either one deflection or a length of canal comprised between two bends of the river. The operations usually begin about the middle of December and continue until about the middle of May, when the rainy season sets in. Naturally the sub contractors make use of the bed of the Chagres as a spoiling ground; the river carries to the sea part of the spoil, but not the whole of it, and when it rises it carries back part of it into the canal, and the speaker has seen railway tracks buried under six feet of earth.

The speaker is not well posted on the financial position of the company, nor as to its expectations, but he has read that the transoceanic traffic had been estimated at 6,000,000 tons annually. The Canal Company, according to its charter, is allowed to charge 15 francs or \$3 per ton, and at these figures it would have an income of \$18,000,000 per year. This seemed reasonable, but it is well to understand that the *ton* at the Panama Canal is not the same as elsewhere. In France, for instance, the official tonnage of a sailing ship is obtained by

multiplying together the three dimensions of the hull in metres, and dividing the product by 3,80; for steamships, the result thus obtained is further reduced by 40 per cent. But, at Panama, the outside length and greatest width, at water line, and the draft (in metres) will be multiplied together, and the result will be the number of tons on which the tolls will be collected. If, therefore, these rules were to be adhered to, the duty at Panama would be nearly trebled, and would amount to about \$9 per ton.

Replying to Mr. Hannaford, who asked where the money was coming from to complete the works, the speaker said that he had no doubt the people of France would furnish the required capital. The company's liabilities were to-day, according to Mr. deLesseps himself, three hundred millions of dollars; but this enormous sum does not represent the money actually spent on the works. The discount on the loans had been as high as 40 per cent., as, for instance, in the loan of 1883, for 300,000,000 francs, which produced 171 millions without any deduction for brokerage, etc. Up to 1884 (he had not the figures for a later date), the company had assumed liabilities for 918 millions of francs, while it had only received 734 millions.

The company had then for years been paying interest on money they had never received, and that could not be kept up long without something like a crash occurring. However, the work already done and the plant on the Isthmus could not be estimated at less than 100 million dollars. If the works were suspended all this would be lost, but with another 100 millions of dollars applied to the works the canal could be opened to traffic, and all then could be saved.

Replying to Professor Bovey as to the probability of the Canal being taken in hand by Great Britain, France and the United States, as an international work—

Mr. E. Deniel said that would be contrary to the charter of the company, which forbade the alienation or mortgage of any of its privileges to a foreign nation or government; any transgression of this would nullify the charter. The company had 12 years in which to do the work, so that it has now about five years to complete the canal, and it does not seem that a momentary suspension of the operations would affect its rights. There is also a clause in the charter providing for a further extension of six years, if at the end of the first twelve years the works are so far advanced that their completion within the extended period may appear probable.

The charter does not make any mention of the canal being either a

sea level or lock canal. By the modification made in the former scheme, from a sea-level to a lock canal, the proportion of work already done, has increased from one quarter to one-half of the total amount, so that the completion of the canal, which was doubtful even during the eighteen years, is now possible and even probable within the twelve years.

The money already advanced has come principally from France; very little having been contributed by the United States or other countries.

He also thought the people of France would advance the additional amount required. It is well to know that it is very difficult to ascertain the exact state of things concerning the canal and the financial condition of the company. Mr. de Lesseps had very powerful enemies, even in France, ready to take hold of the enterprise if they had the opportunity. When the speaker was in Panama last winter, he wondered of what use the large contracting firms with the expensive staff of engineers, accountants, clerks and other employees, could be, since the work was actually performed by the sub-contractors, but he was told that nobody there expected to see the canal company carry out the works to the end; but if it could push it far enough, then, when the money would become scarce, the contractors could and would bring their respective contracts to completion, and be recouped out of the first proceeds of the canal. All the firms above mentioned are backed by large French banking establishments which could come forward in an emergency.

On the 1st Jan., 1888, Messrs. Slaven & Co. were far from having finished their work, having then done about three-fifths of it. It was all dredging through mud, sand and clay, with the exception of four ledges of rock aggregating about two miles in length. The plant used by Messrs. Slaven & Co. (American Dredging and Contracting Co.) has been described above, and consists of elevator dredges. The materials excavated are deposited on each side of the canal, through the "long couloir." The result of the operations has been the drainage of the marshes and the consolidation of the ground through the region traversed by the canal in the neighbourhood of Colon. The works had been opened simultaneously at different places, the dredges having been sent up by the Rio Chagres, and, when in position, dredging in the line of the canal on both sides of the river.

The accompanying plans (Plate I) show all the work done in the canal and deflections up to January 1st, 1888, the work remaining to be done

to complete the lock canal, and the work subsequently to be done to complete the sea level canal.

Mr. Deniel could not give any information as to the high charges on ocean freights, or whether such charges would prove prohibitive. He had not studied all the different aspects of the question of the Panama Canal, but simply the engineering features of the enterprise.

The following statement, as giving more detailed information concerning the financial position of the Panama Canal Company, may be of interest to the members:—

On January 1st, 1888, the liabilities of the company amounted to \$329,505,100, as follows:—

Original capital.....				\$60,000,000
Loan of 1882 bearing interest at 5 per cent....				25,000,000
“ 1883 “ “ 3 “				60,000,000
“ 1884 “ “ 4 “				34,129,200
“ 1885 “ “ 4 “				6,837,500
“ 1886 “ “ 3 “				91,760,000
“ 1887 “ “ 3 “				51,778,400
			Total	\$329,505,100

From which must be reduced :

Promoters' shares (10,000 at \$100).....	\$1,000,000	
Discount on loan of 1882	3,125,000	
“ “ 1883.....	25,800,000	
“ “ 1884.....	8,809,500	
“ “ 1885.....	1,765,000	
“ “ 1886.....	51,462,505	
“ “ 1887.....	28,996,355	120,958,360

Leaving a sum of..... \$208,546,740

Representing the cash raised up to that date. The amount paid up to the same date on interests, amortization, brokerage, etc., etc., is about .

Interest paid on original capital.....	\$13,500,000
Interest and amortization on loan, 1882...	8,500,000
“ “ “ 1883...	11,784,000
“ “ “ 1884...	6,061,347
“ “ “ 1885...	815,030
“ “ “ 1886...	4,588,600

Brokers' and bankers' fees, say $2\frac{1}{2}$ per cent.	8,237,628	
Cash paid for charter to promoters.....	1,000,000	
Preliminary expenses.....	4,520,000	
Panama Railway (68,534 out of 10,000 shares).....	18,775,000	77,781,605

Leaving a sum of..... \$130,765,135
to defray all expenses such as salaries, buildings, plant, excavation, etc.,
etc., including \$25,000,000 for the construction of the locks.

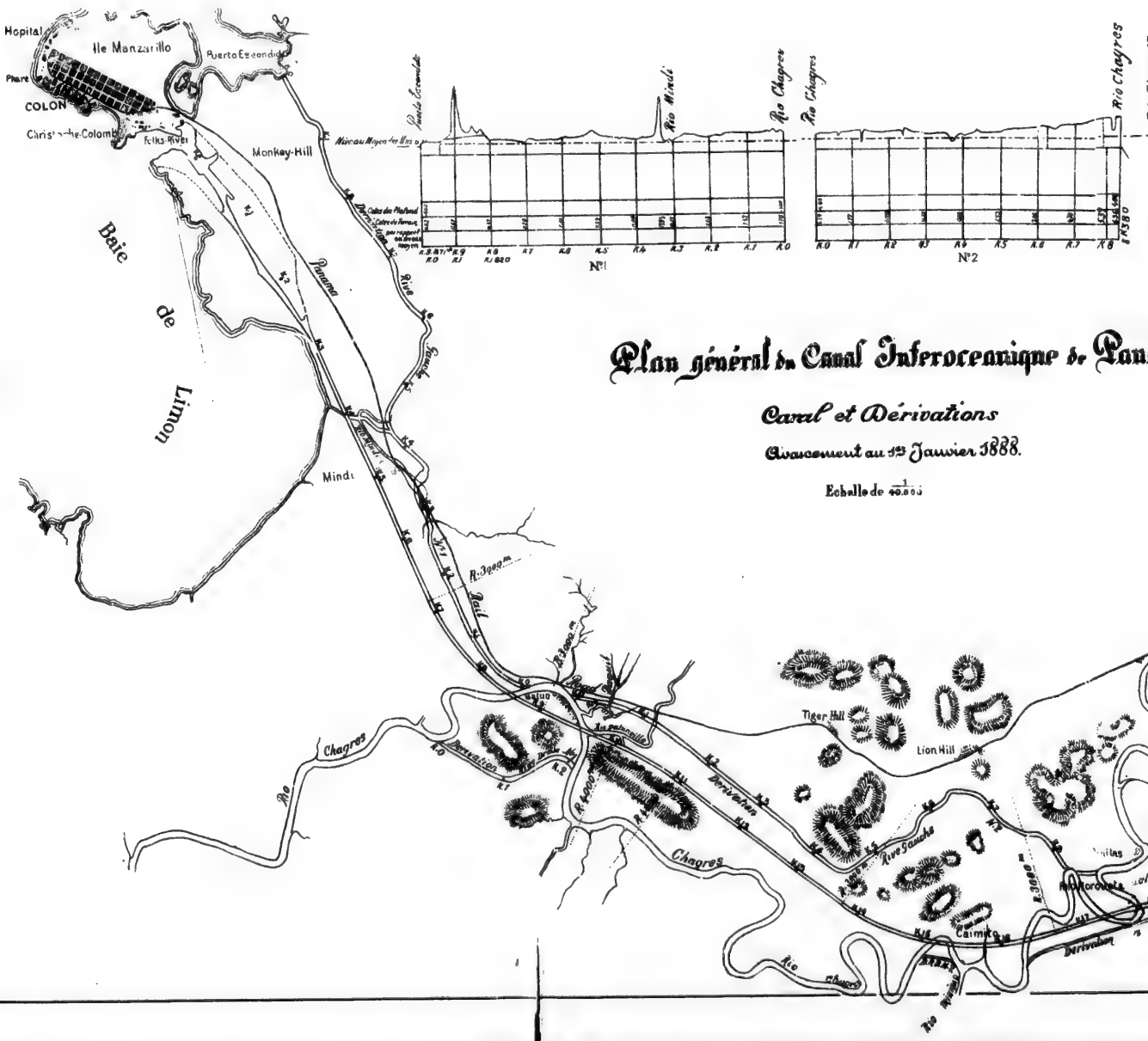
781,605

765,135

on, etc.,



OCEAN ATLANTIQUE



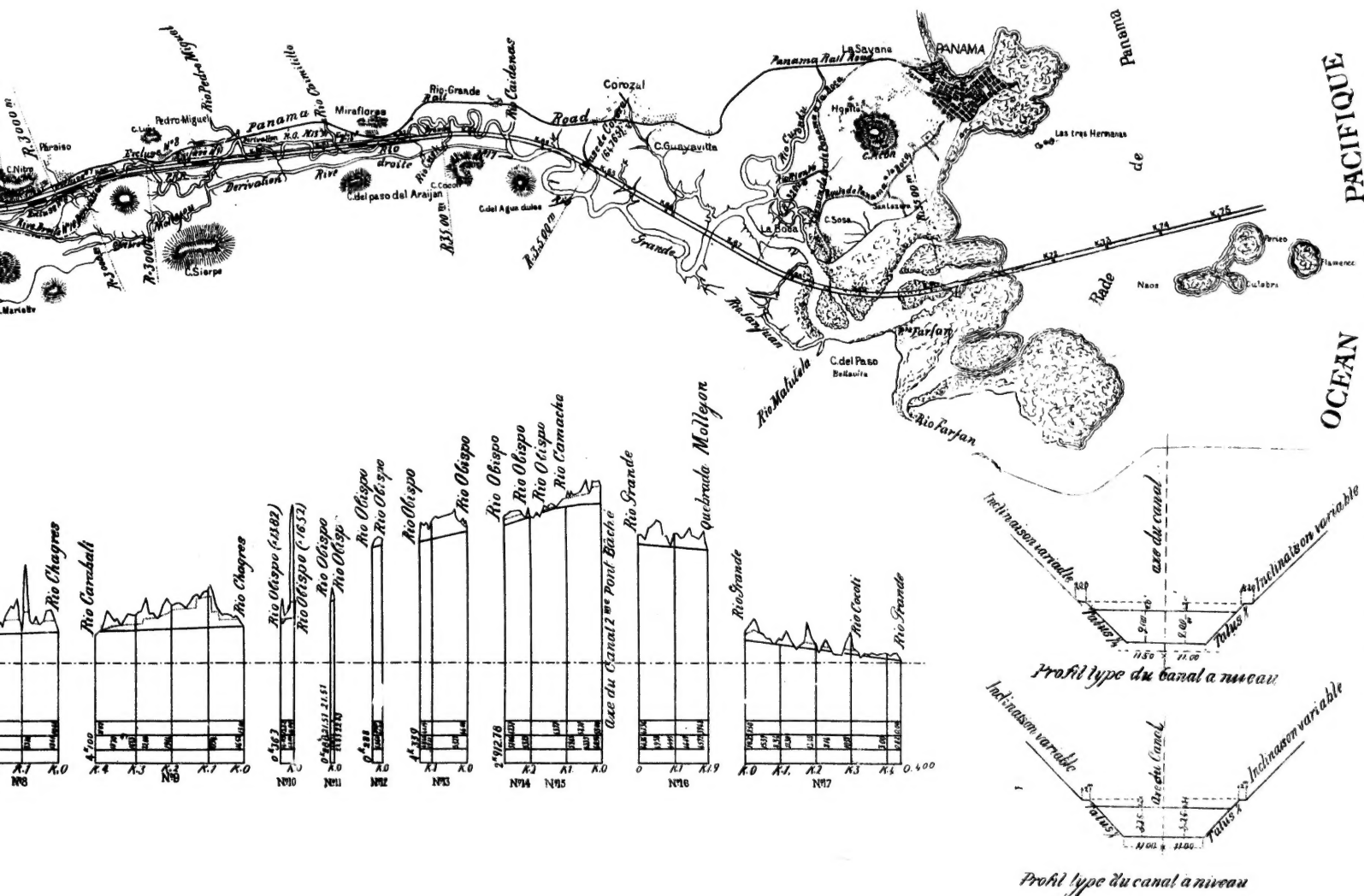
Plan général du Canal Interocéanique de Panama

Canal et Dérivations

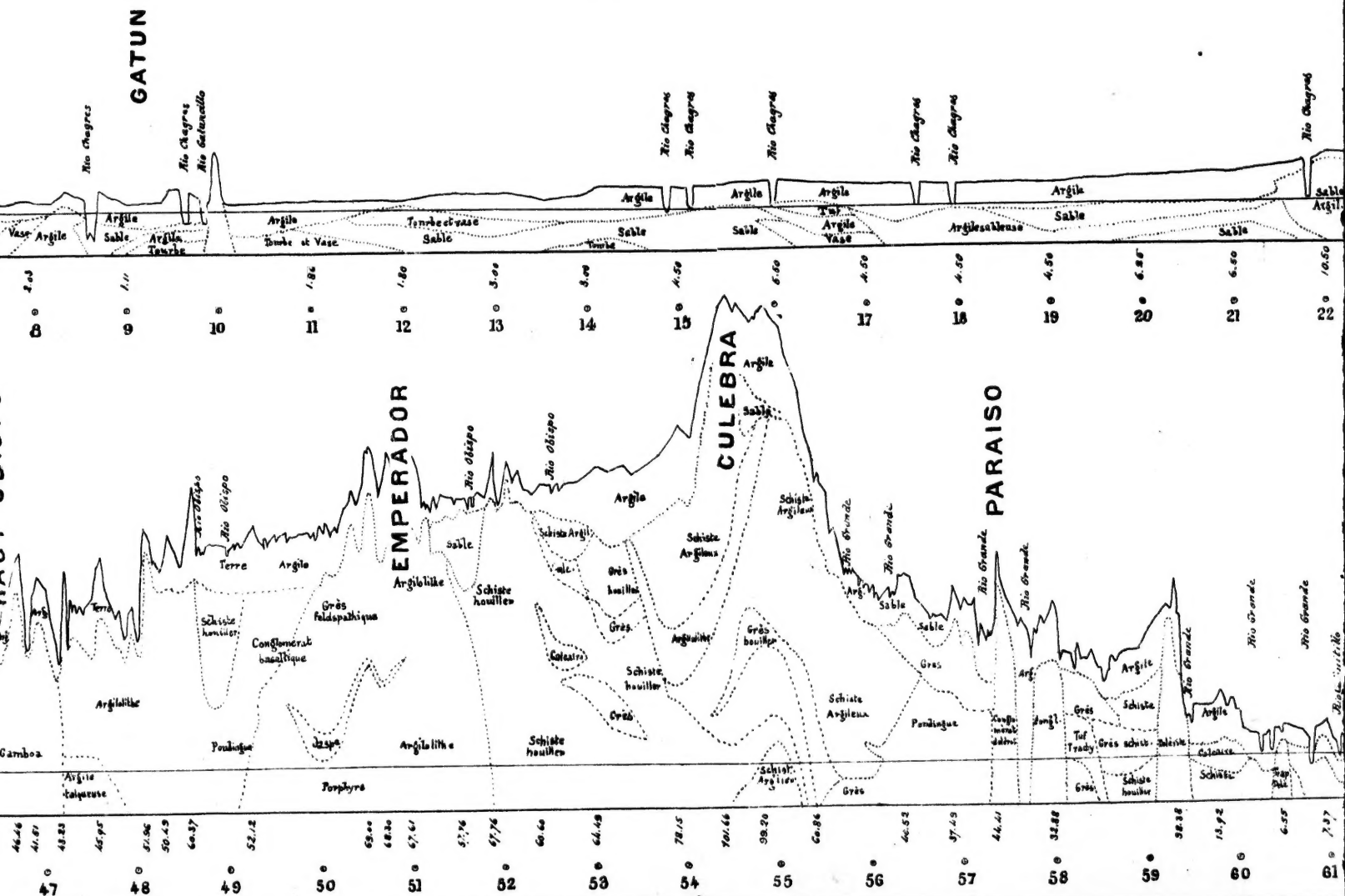
Avancement au 1^{er} Janvier 1888.

Echelle de 1:1000

PANAMA CANAL—PLATE I.



PROFIL GEOLOGIQUE SUIVANT L'AXE DU CANAL
PANAMA CANAL.



NAL

PLATE II

